



脉冲星和快速射电暴的星际闪烁研究

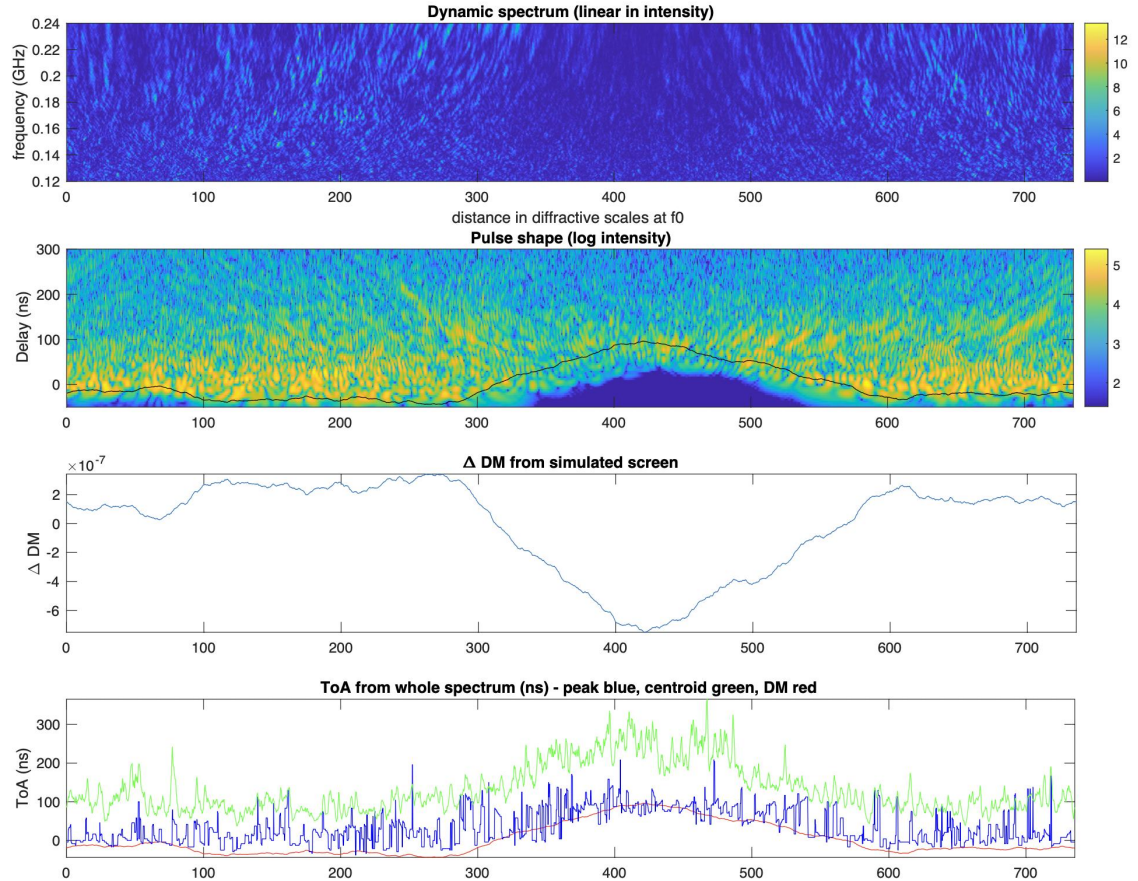
吴子为

合作导师：朱炜玮
中国科学院国家天文台



To improve pulsar timing precision with LOFAR

LOFAR HBA:
120-180 MHz



Pulsar scintillation studies with LOFAR: I. The census

Table 1. Properties of the observations and scintillation characteristics for the 15 pulsars with detectable scintillation.

PSR name (J2000)	DM (pc cm ⁻³)	Period (s)	Station	Date	Length (h)	Δf (kHz)	Δt (s)	$\Delta\nu_d^{(a)}$ (kHz)	$\tau_d^{(a)}$ (min)	u	t_r (day)	α
J0034-0721	10.9	0.943	FR606	2020-10-01	1.0	5	10	67.1(5)	–	67	–	5.0(5)
J0332+5434	26.8	0.715	FR606	2020-12-08	0.5	0.3	10	0.91(3)	0.78(0)	570	206	4.46(6)
J0814+7429	5.8	1.292	DE604	2017-04-29	3.0	5	10	326(16)	19.3(9)	30	13	4.4(7)
J0826+2637	19.5	0.531	Core	2019-12-03	0.5	1	5	5.28(2)	0.64(0)	240	26	4.1(2)
J0837+0610	12.9	1.274	DE601	2020-01-19	2.0	5	10	9.95(4)	1.79(1)	174	40	4.5(1)
J0953+0755	3.0	0.253	DE601	2016-01-04	5.0	195	60	916(57)	18(1)	18	4	3.7(6)
J1136+1551	4.8	1.188	DE601	2015-04-10	2.0	5	10	6.3(2)	0.48(0)	218	13	4.1(5)
J1239+2453	9.3	1.382	FR606	2020-05-20	1.0	5	10	36.6(4)	2.15(2)	91	14	3.2(3)
J1607-0032	10.7	0.422	FR606	2020-09-08	1.0	1.25	10	20.8(6)	6.8(1)	120	137	4.6(3)
J1921+2153	12.4	1.337	DE609	2018-08-26	1.7	5	10	22.1(1)	1.1(0)	116	11	4.0(3)
J1932+1059	3.2	0.227	FR606	2020-12-30	1.0	5	10	59.8(9)	3.2(1)	71	13	4.0(4)
J2018+2839	14.2	0.558	DE603	2019-12-27	2.0	5	10	–	4.51(4)	–	–	–
			FR606	2020-12-15	1.0	0.3	10	2.9(8)	3.95(2)	321	632	4.2(3)
J2022+2854	24.6	0.343	Core	2019-12-03	0.5	1	5	5.88(4)	2.05(1)	226	97	6.6(3)
J2022+5154	22.6	0.529	Core	2019-12-03	0.5	1	5	4(5)	–	280	–	–
J2219+4754	43.5	0.538	Core	2020-01-15	0.5	0.08	5	0.23(1)	0.54(0)	1142	572	4.3(2)

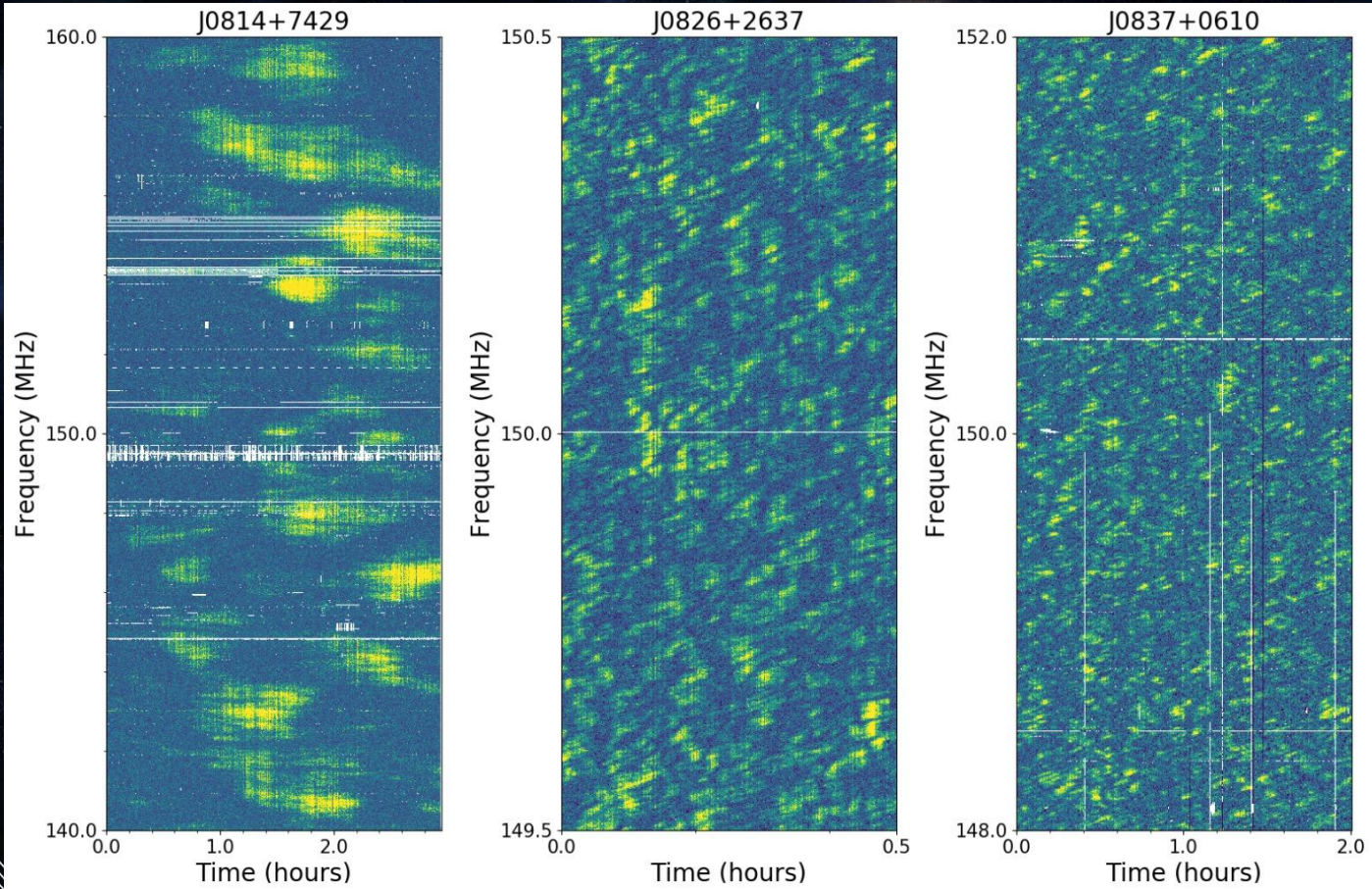
Pulsar scintillation studies with LOFAR: I. The census

Table 2. Observational data for pulsars for which the scintillation bandwidth $\Delta\nu_d$ could not be successfully derived.

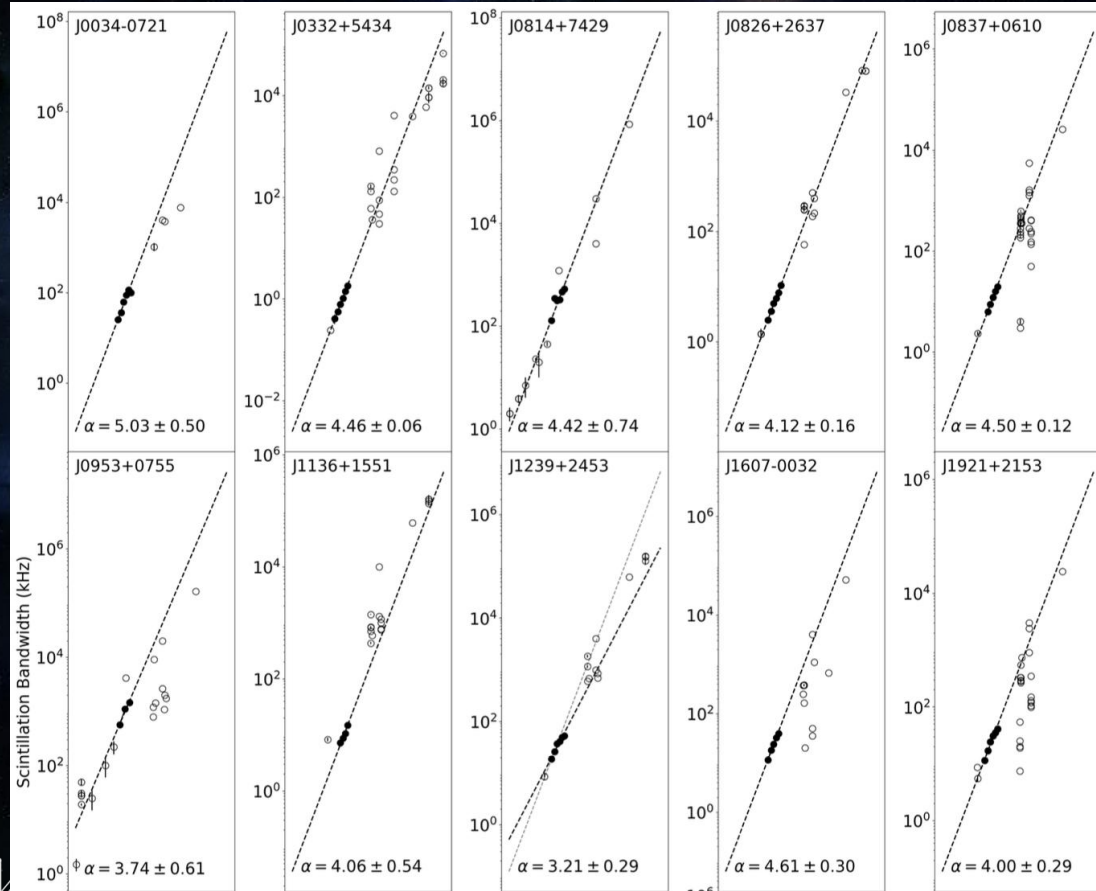
PSR name (J2000)	DM (pc cm^{-3})	Period (s)	Station	Date	Length (h)	Δf (kHz)	Δt (s)	Ref.	Note ^(a)
J0034-0534	13.8	0.002	FR606	2020-12-29	1.0	1.25	10		
J0323+3944	26.2	3.032	FR606	2021-03-17	1.0	0.3	10	Smith & Wright (1985)	Low S/N
J0922+0638	27.3	0.431	FR606	2020-09-09	1.0	1.25	10	Bhat et al. (1999b)	
J0946+0951	15.3	1.098	FR606	2020-12-30	1.0	1.25	10		Low S/N
J1012+5307	9.0	0.005	Core	2020-12-03	0.5	32	5	Levin et al. (2016)	Low S/N
J1300+1240	10.2	0.006	FR606	2021-03-18	1.0	0.3	10	Gothoskar & Gupta (2000)	
J1509+5531	19.6	0.740	FR606	2020-12-01	1.0	0.3	10	Bhat et al. (1999b)	Low S/N
J1537+1155	11.6	0.038	FR606	2020-12-30	1.0	1.25	10	Johnston et al. (1998)	
J1645-0317	35.8	0.388	DE601	2021-11-30	2.0	5	10	Smirnova et al. (2006)	Insufficient Δf
J1740+1311	48.7	0.803	FR606	2020-06-25	1.0	0.16	10	Cordes et al. (2006)	
J1857+0943	13.3	0.005	FR606	2021-03-18	1.0	0.6	10	Levin et al. (2016)	
J1959+2048	29.1	0.002	Core	2021-07-26	0.5	32	10	Main et al. (2017)	
J2048-1616	11.5	1.962	FR606	2020-09-08	1.0	1.25	10	Bhat et al. (1999b)	Low S/N
J2113+2754	25.1	1.203	FR606	2021-03-18	1.0	0.6	10		Low S/N
J2313+4253	17.3	0.349	FR606	2021-03-17	1.0	0.3	10	Bhat et al. (1999b)	Low S/N
J2330-2005	8.5	1.644	FR606	2020-09-08	1.0	1.25	10	Bhat et al. (1999b)	

Pulsar scintillation studies with LOFAR: I. The census

Examples:



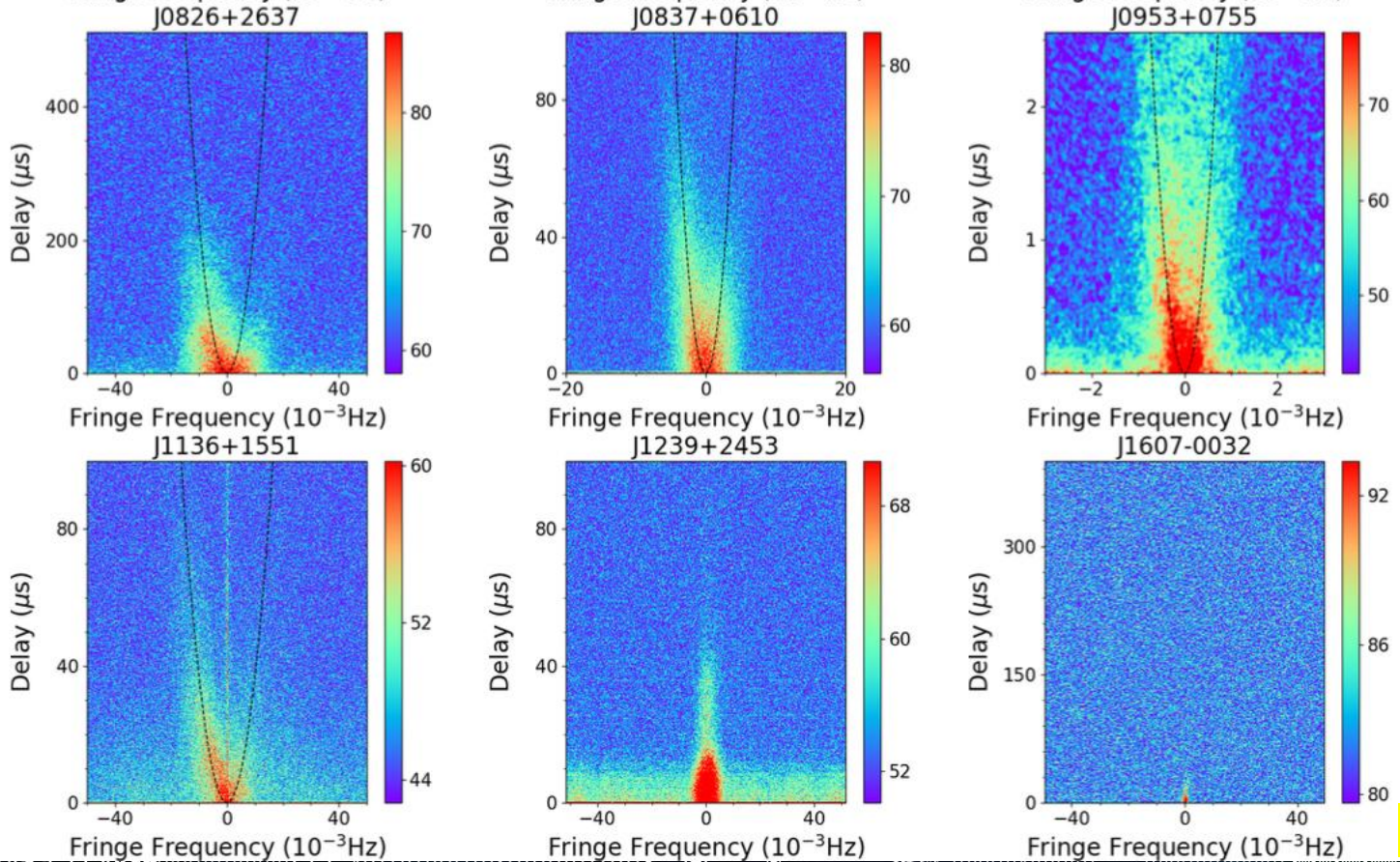
Examples:



Wu et al. A&A 2022

Pulsar scintillation studies with LOFAR: I. The census

Examples:



Summary and update:

1. No MSP in this work
2. Long term scintillation monitoring for 15 pulsars
3. Power-law index mostly ~ 4.4
4. Faint and diffuse scintillation arcs at Lower frequency



Dual-frequency scattering study of PSR J0826+2637

Power-Law Index (4 or 4.4): scattering and scintillation



Dual-frequency scattering study of PSR J0826+2637

$$2\pi \tau_{\text{sc}} \Delta\nu_{\text{d}} = 1$$

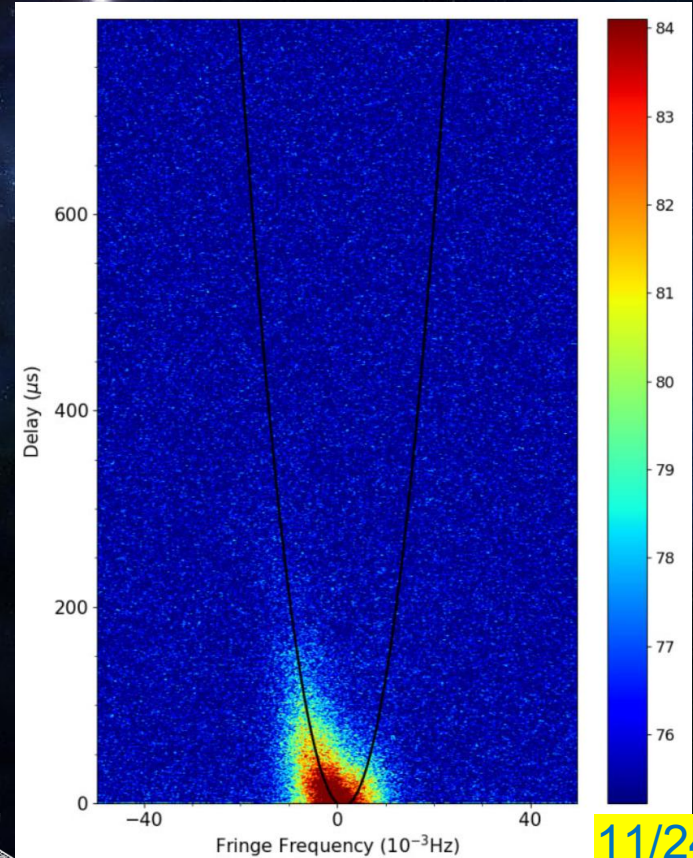
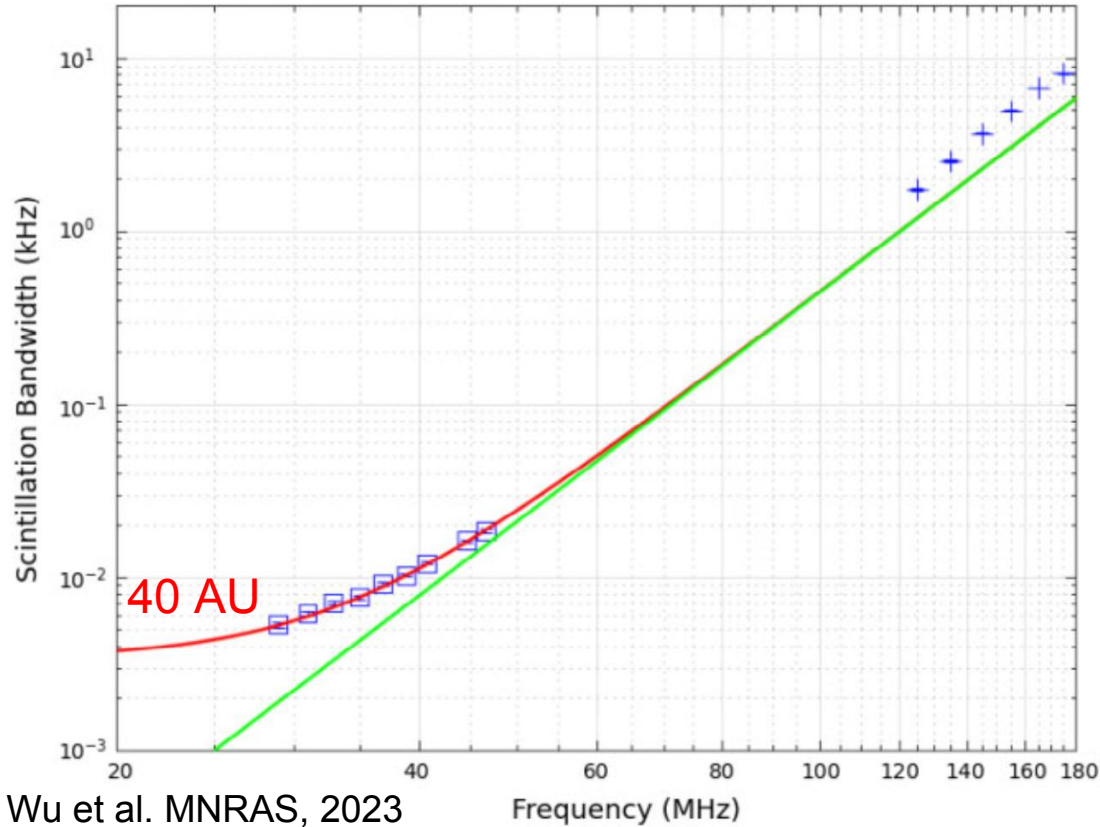
NenuFAR: 10 - 80 MHz

LOFAR HBA: 120 - 180 MHz

near-simultaneous



Dual-frequency scattering study of PSR J0826+2637



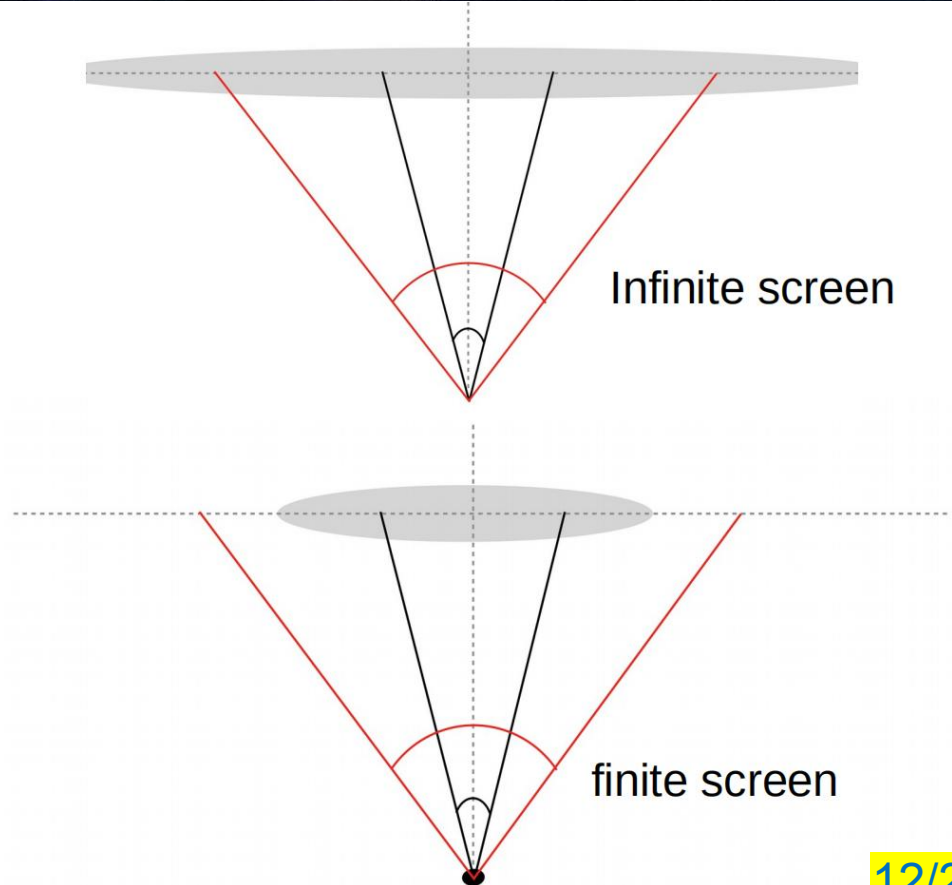
Dual-frequency scattering study of PSR J0826+2637

$$\begin{aligned}
 B(\theta) &= \exp(-[(\theta/\theta_{\text{scat}})^2 + (\theta/\theta_{\text{cloud}})^2]) \\
 &= \exp[-\theta^2(1/\theta_{\text{scat}}^2 + 1/\theta_{\text{cloud}}^2)] \\
 &= \exp(-(\theta/\theta_{\text{tot}})^2)
 \end{aligned}$$

Scintillation bandwidth:

$$\Delta\nu_d = \frac{c}{2\pi(1-s)D_p\theta_{\text{tot}}^2}$$

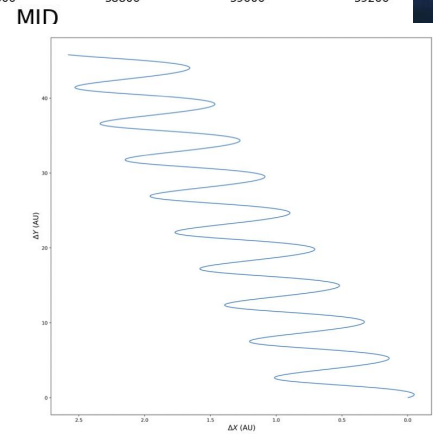
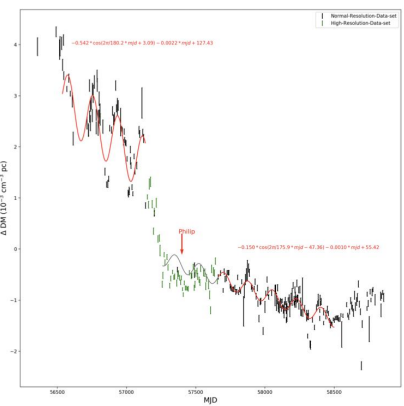
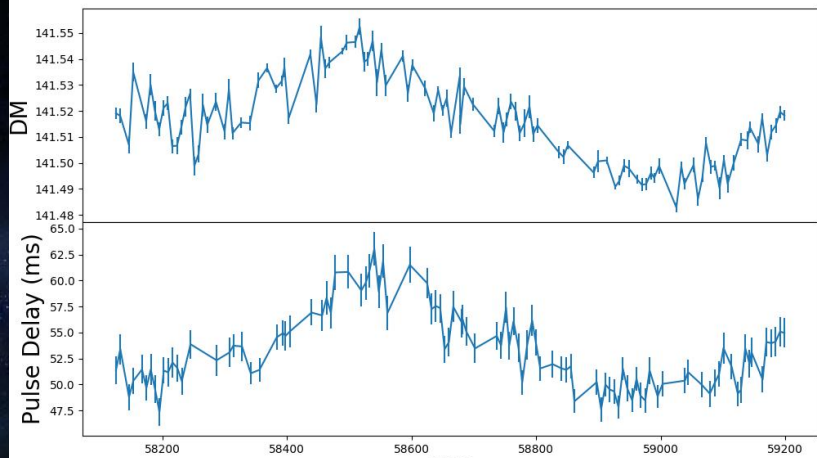
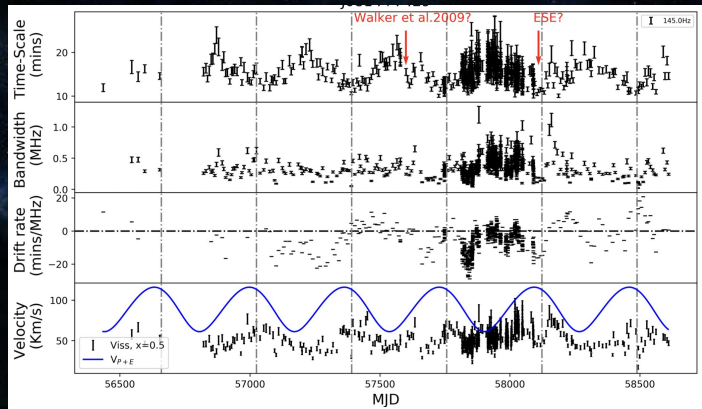
Wu et al. MNRAS, 2023



Summary and update:

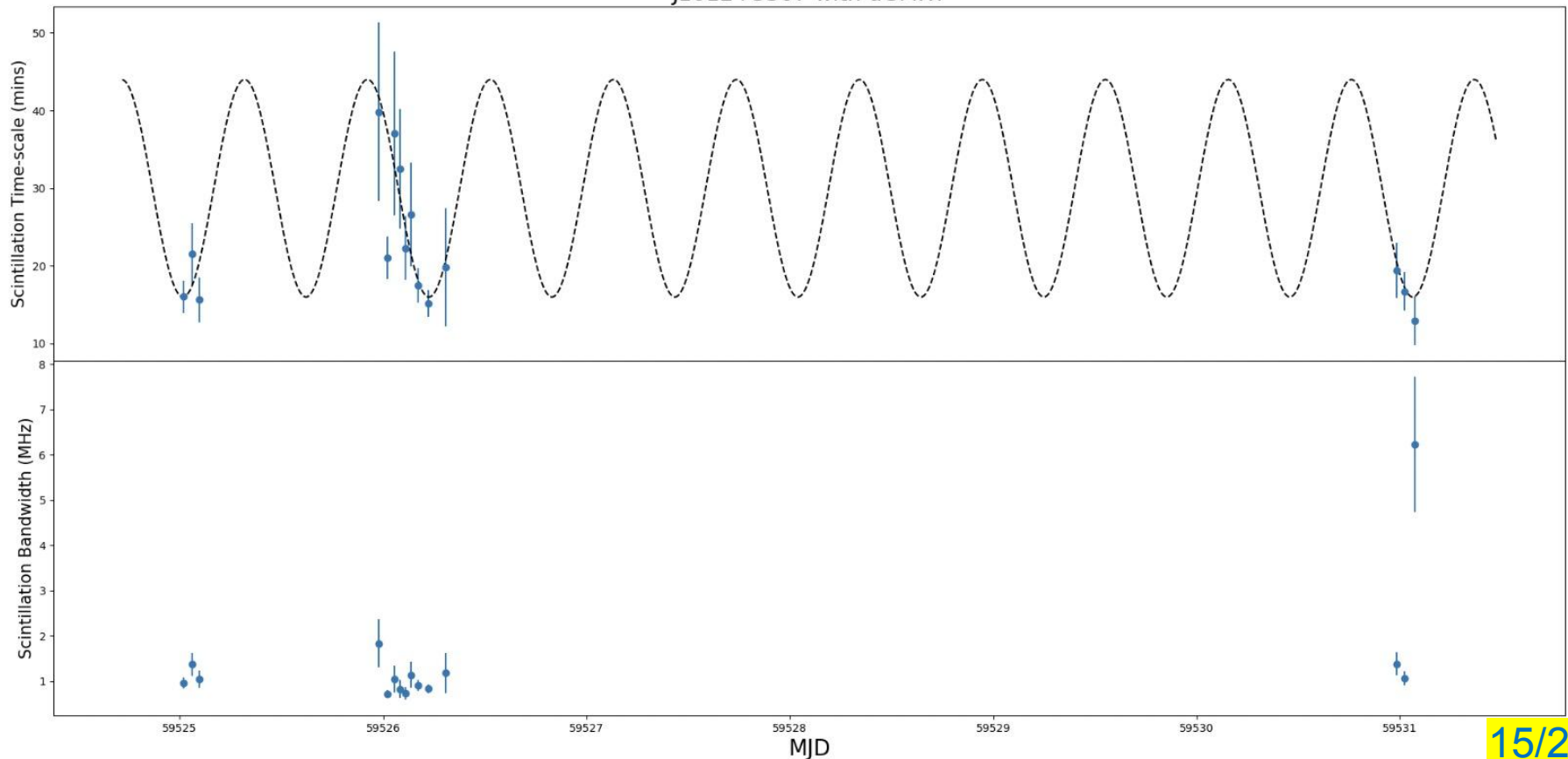
1. Finite scattering screen model
2. more pulsars are being tested
3. DM
4. Pulsar Timing Precision





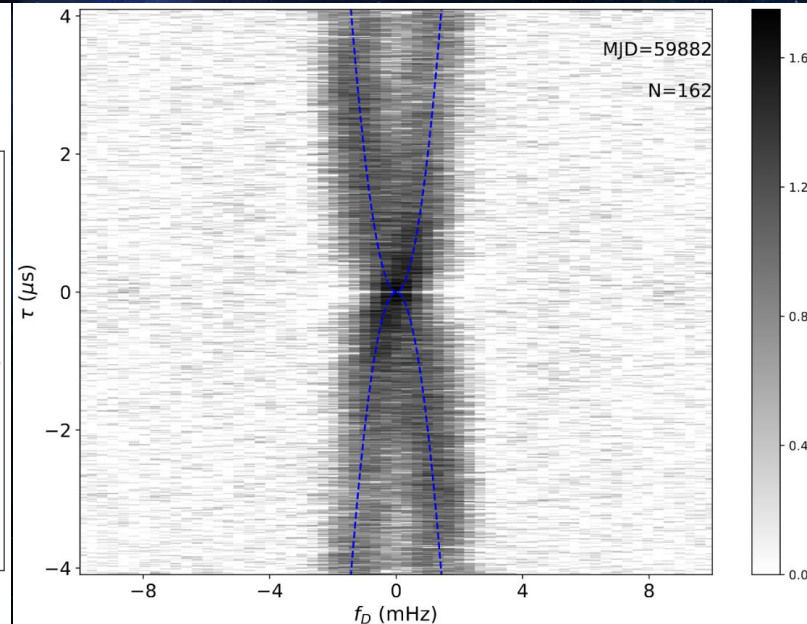
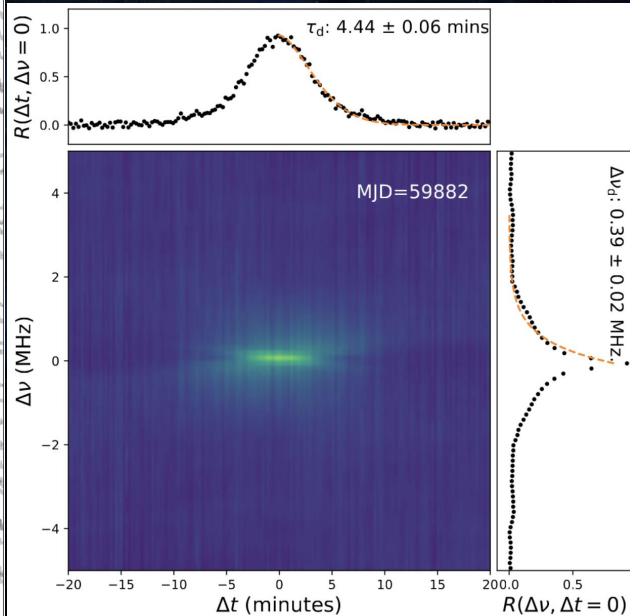
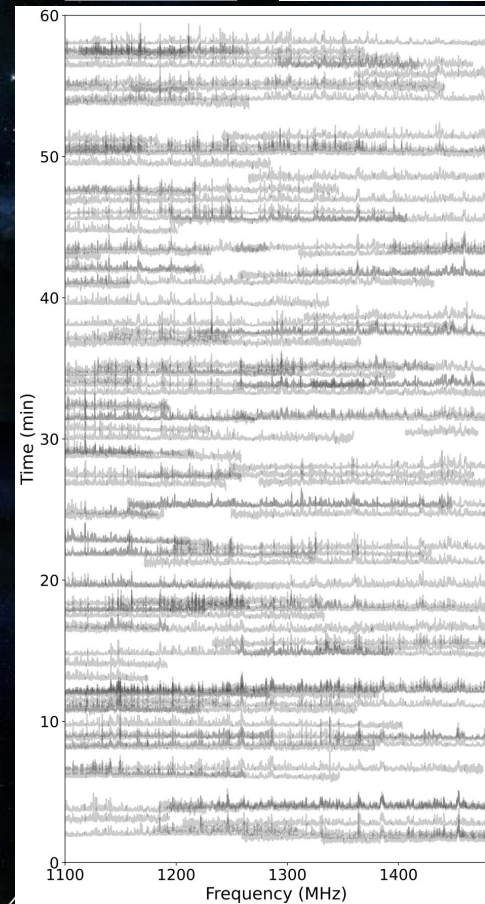
研究动机 - FRB scintillation

J1012+5307 with uGMRT



FRB 20220912A scintillation

Wu et al. SCPMA,
2024a



FRB 20220912A scintillation

1. Scintillation Velocity:

$$V_{\text{eff}} = (1 - s)(V_{\text{FRB}} + V_0) + sV_E - V_{\text{sc}}(s).$$

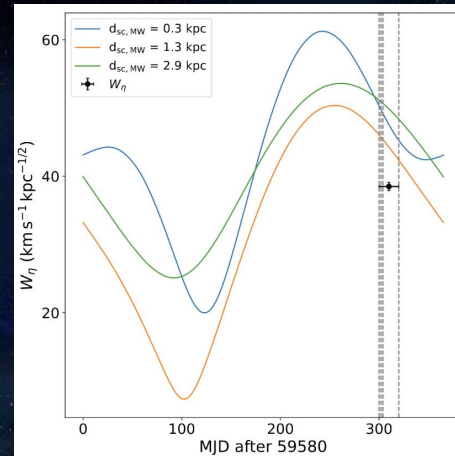
2. Scintillation in HG or MW:

2.1 Scintillation in HG:

$$\eta \approx \frac{cd_{\text{sc,HG}}}{2v^2} \frac{1}{[(V_{\text{FRB}} + V_0 - V_{\text{sc}}) \cos \psi]^2},$$

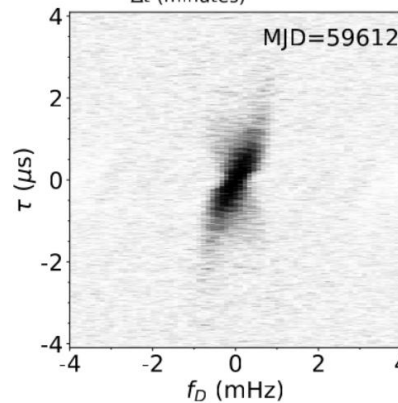
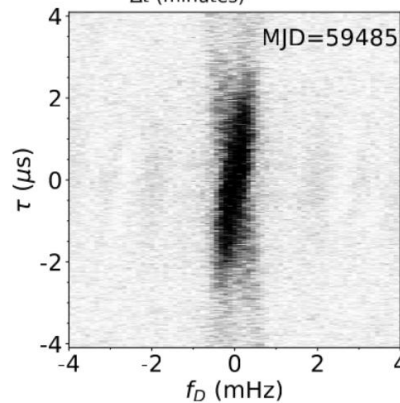
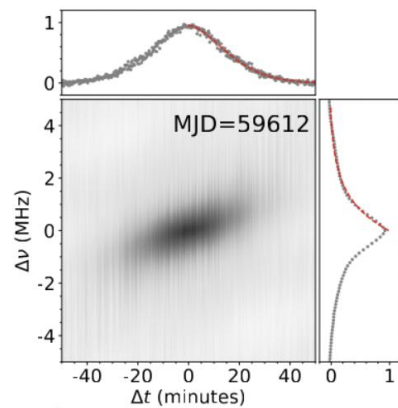
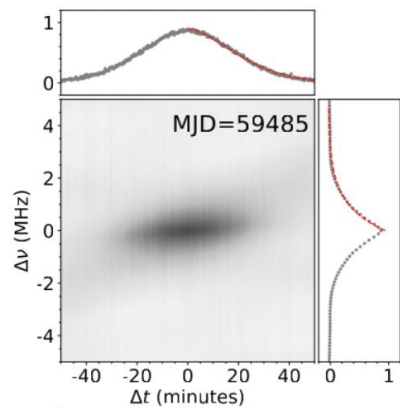
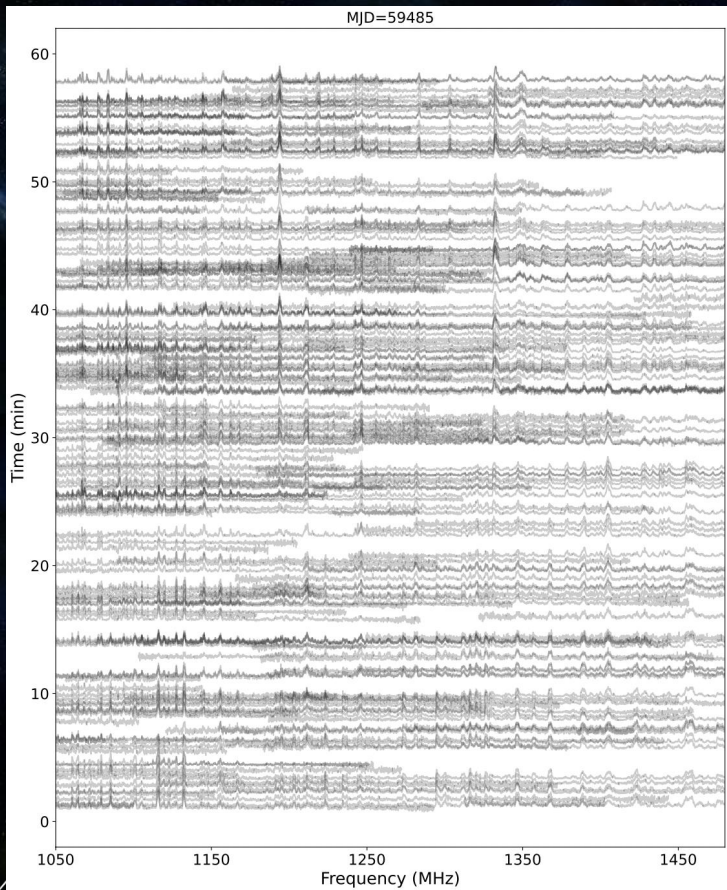
2.2 Scintillation in MW:

$$\eta \approx \frac{cd_{\text{sc,MW}}}{2v^2} \frac{1}{[(V_E - V_{\text{sc}}) \cos \psi]^2}.$$

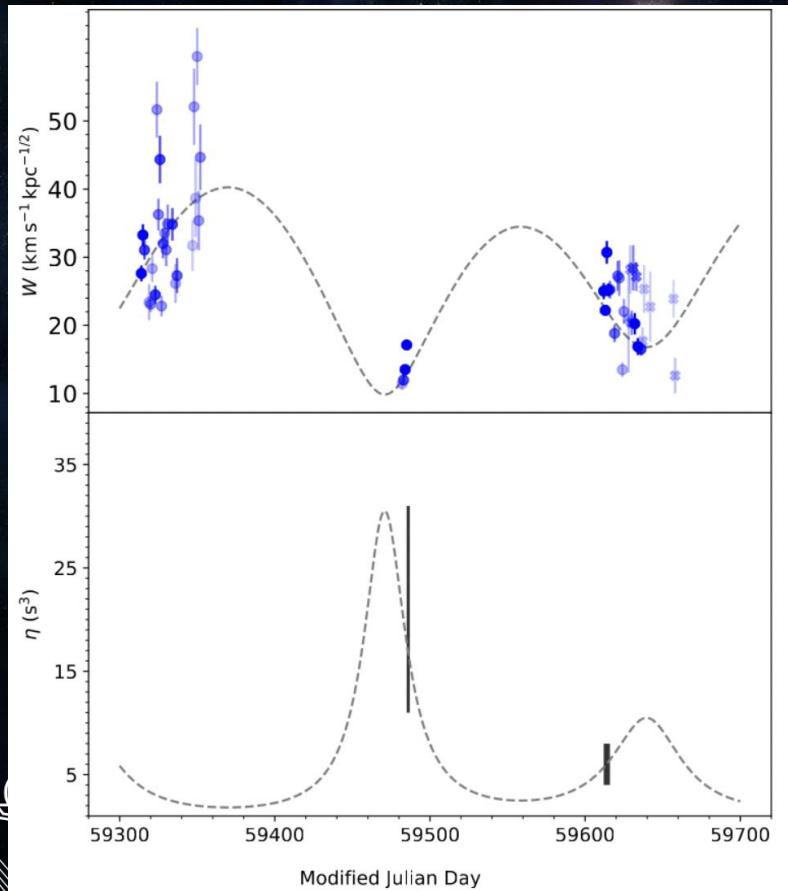


Wu et al. SCPMA,
2024a

FRB 2020124A scintillation

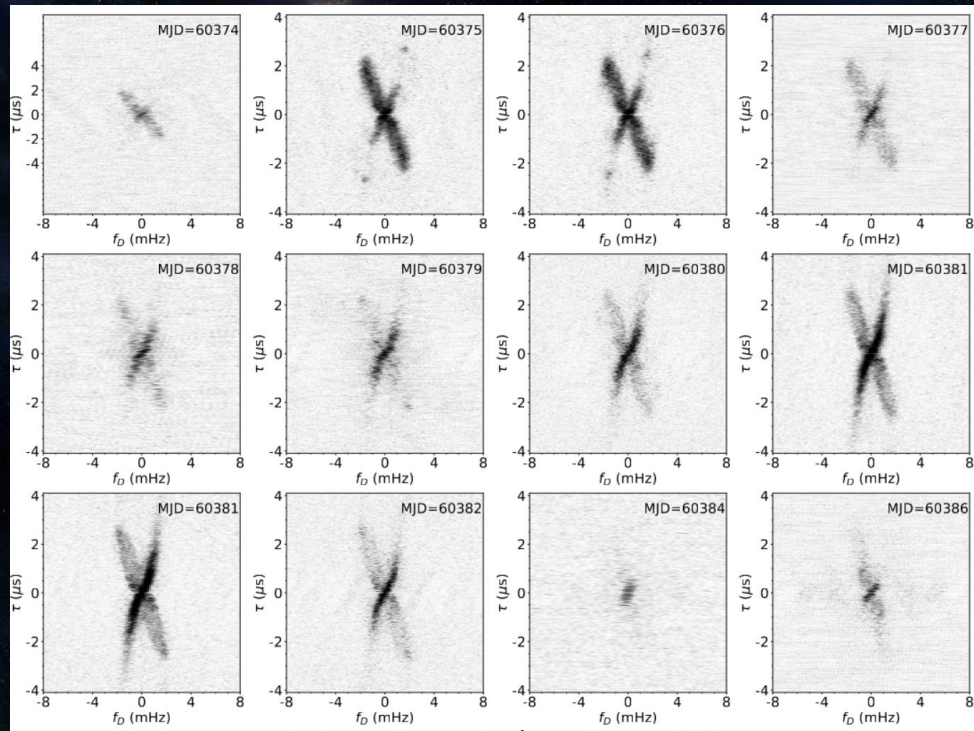
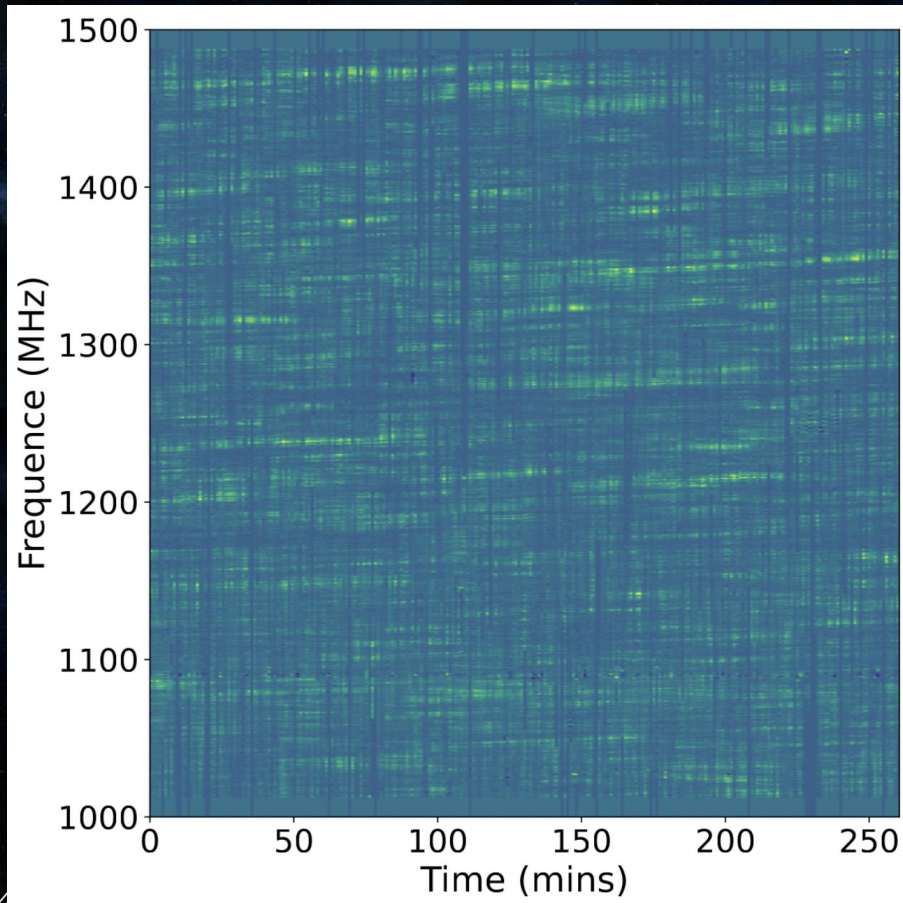


FRB 2021124A scintillation

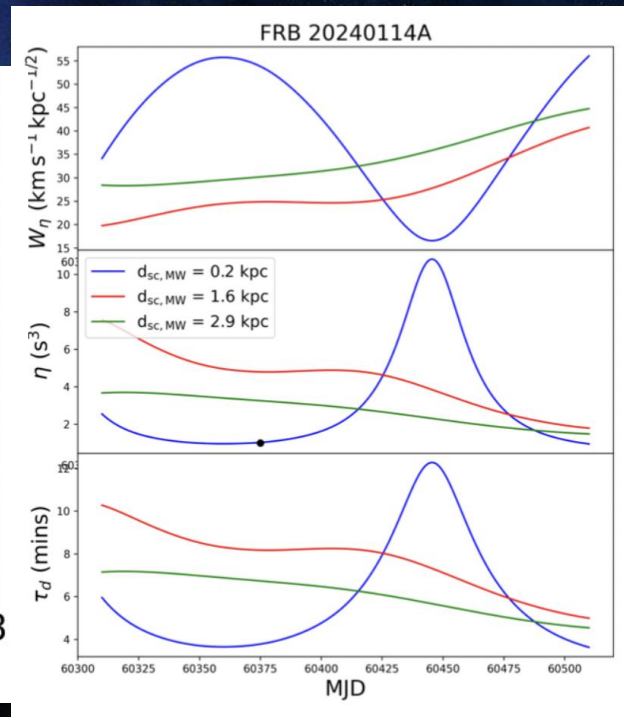
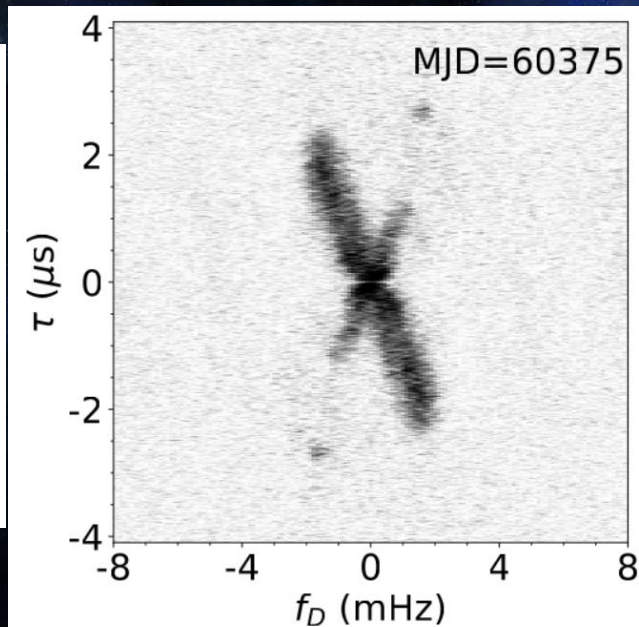
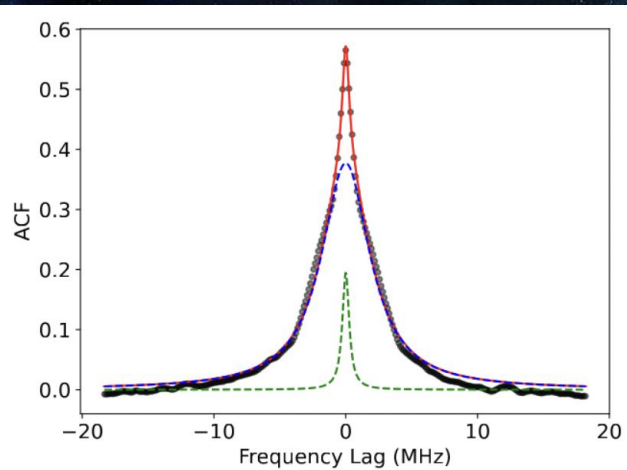


Wu et al. ApJL, 2024b

FRB 20240114A scintillation - Preliminary



FRB 20240114A scintillation - Preliminary



FRB Scintillation with FAST

Summary and update:

1. Scintillation arc detected: FRB 20220912A
2. Annual variation in scintillation velocity: FRB 20201124A
3. FRB 20240114A:
precision
non-1 modulation index,
two frequency scale,
arc-let
4. Scintillation time-sale: FRB 20220529A, FRB 20230607A



Scintillation Arc from FRB 20220912A

Zi-Wei Wu^{1*}, Robert A. Main², Wei-Wei Zhu^{1,3*}, Bing Zhang⁴, Peng Jiang^{1,5}, Jia-Rui Niu^{1,6}, Jin-Lin Han^{1,6}, Di Li^{1,7}, Ke-Jia Lee^{1,8,9}, Dong-Zi Li¹⁰, Yuan-Pei Yang¹¹, Fa-Yin Wang^{12,13}, Rui Luo^{14,15}, Pei Wang¹, Chen-Hui Niu¹, Heng Xu¹, Bo-Jun Wang^{8,9}, Wei-Yang Wang^{6,8}, Yong-Kun Zhang^{1,6}, Yi Feng¹⁶, De-Jiang Zhou^{1,6}, Yong-Hua Xu¹⁷, Can-Min Deng¹⁸, and Yu-Hao Zhu^{1,6}

Pulsar scintillation studies with LOFAR

I. The census

Ziwei Wu¹, Joris P. W. Verbiest^{1,2}, Robert A. Main², Jean-Mathias Grießmeier^{3,4}, Yulan Liu¹, Stefan Osłowski⁵, Krishnakumar Mochickal Ambalappat^{2,1}, Ann-Sofie Bak Nielsen^{2,1}, Jörn Künsemöller¹, Julian Y. Donner^{2,1}, Caterina Tiburzi⁶, Nataliya Porayko², Maciej Serylak^{7,8}, Lars Künkel¹, Marcus Brüggen⁹, and Christian Vocks¹⁰

Scintillation Velocity and Arc Observations of FRB 20201124A

Ziwei Wu¹, Weiwei Zhu^{1,2}, Bing Zhang^{3,4}, Yi Feng⁵, JinLin Han^{1,6}, Di Li^{1,7,8}, Dongzi Li⁹, Rui Luo¹⁰, Chenhui Niu¹¹, Jiarui Niu^{1,6}, Bojun Wang¹, Fayin Wang^{12,13}, Pei Wang¹, Weiyang Wang¹⁴, Heng Xu¹, Yuanpei Yang¹⁵, Yongkun Zhang^{1,6}, Dejiang Zhou^{1,6}, Yuhao Zhu^{1,6}, Can-Min Deng¹⁶, and Yonghua Xu¹⁷
(FAST FRB Key Science Project)

Pulsar scintillation studies with LOFAR: II. Dual-frequency scattering study of PSR J0826+2637 with LOFAR and NenuFAR

Ziwei Wu^{1,2*}, William A. Coles³, Joris P. W. Verbiest^{2,4}, Krishnakumar Mochickal Ambalappat^{2,4}, Caterina Tiburzi⁵, Jean-Mathias Grießmeier^{6,7}, Robert A. Main⁴, Yulan Liu^{1,2}, Michael Kramer^{4,8}, Olaf Wucknitz⁴, Nataliya Porayko⁴, Stefan Osłowski⁹, Ann-Sofie Bak Nielsen^{2,4}, Julian Y. Donner^{2,4}, Matthias Hoft¹⁰, Marcus Brüggen¹¹, Christian Vocks¹², Ralf-Jürgen Dettmar¹³, Gilles Theureau^{6,7,14}, Maciej Serylak^{15,16}, Vladislav Kondratiev¹⁷, James W. McKee^{18,19}, Golam M. Shaifullah^{5,20,21}, Ihor P. Kravtsov^{22,23}, Vyacheslav V. Zakharenko²², Oleg Ulyanov²², Olexandr O. Konovalenko²², Philippe Zarka^{23,24}, Baptiste Ceconi^{23,24}, Léon V. E. Koopmans²⁵ and Stéphane Corbel^{24,26}

1. FAST FRB KSP and FAST pulsar scintillation

2. LOFAR KSP

Submission: LOFAR2.0 Large Programmes – Full proposal

LOFAR2.0 Pulsar & Fast Transient Surveys

Jason Hessels^{1,2}, Cees Bassa¹, Maura Pilia³, Charlotte Sobey⁴, Ben Stappers⁵, Shivani Bhandari^{2,6}, Leszek Blazkiewicz⁷, Marta Burgay³, Manisha Caleb⁸, Jesus Alberto Cázares⁹, Pragya Chawla², Alessandro Corongiu³, Marcin Gawronski¹⁰, Aaron Golden¹¹, J.-M. Griessmeier^{12,13}, Akshatha Gopinath², Gemma Janssen^{1,14}, Aris Karastergiou¹⁵, Evan Keane¹⁶, Mark Kennedy¹⁷, Franz Kirsten¹⁸, Vladislav Kondratiev¹⁹, Kamen Kozarev¹⁹, Michael Kramer^{20,5}, David McKenna^{21,16}, Daniele Michilli^{22,23}, Leah Morabito^{24,25}, Rouhin Nag³, Cherry Ng²⁶, Kenzie Nimmo²², Aditya Parthasarathy¹, Ziggy Pleunis²⁶, Andrea Possenti³, Harry Qiu²⁷, Kaustubh Rajwade^{1,5}, Alessandro Ridolfi³, Antonia Rowlinson^{1,2}, Maciej Serylak^{27,28}, Xiaoxi Song¹, Laura Spitler²², Chia Min Tan²⁹, Caterina Tiburzi³, Sander ter Veen¹, Danyal Usman^{1,2,1}, Bin Wang³⁰, Emma van der Wateren^{1,14}, Patrick Weltevrede⁵ and Ziwei Wu³¹

Submission: LOFAR2.0 Large Programmes – Full proposal

PURR – PULSARS and Repeaters Research, a Pulsar and Fast Transient Monitoring Project

C. Tiburzi¹, C. G. Bassa², J. W. T. Hessels^{2,3}, G. H. Janssen^{2,4}, E. F. Keane⁵, M. A. Krishnakumar^{6,7}, L. S. Oswald^{8,9}, M. Pilia¹, C. Sobey^{10,11}, X. Song², M. Trudu¹, J. P. W. Verbiest¹², P. Weltevrede¹³, F. Abbate^{1,6}, J. Antoniadis^{14,6}, A. Antonova¹⁵, A. Basu¹³, R. Basu¹⁶, A. V. Bilous¹⁷, C. Blanchard¹⁸, L. Blazkiewicz¹⁹, M. Brionne¹⁸, M. Burgay¹, M. Brüggen²⁰, J. A. Cázares²¹, A. Chalumeau^{22,23}, B. Ciardi²⁴, A. Corongiu¹, P. Flisck¹⁹, M. P. Gawronski²⁵, A. Golden²⁶, J.-M. Grießmeier^{18,27}, M. Hoeft²⁸, H. Hu⁶, F. Iraci^{1,29}, F. Jankowski^{18,13}, O. A. Johnson⁵, A. Karastergiou⁸, M. R. Kennedy³⁰, J. Kijak¹⁶, V. I. Kondratiev², K. Kozarev¹⁵, M. Kramer^{6,13}, A. Krankowski¹⁹, J. van Leeuwen², W. Lewandowski¹⁶, G. A. Lowes^{31,32}, K. Liu⁶, Y. Liu^{33,34}, R. A. Main^{35,36}, J. W. McKee^{31,32}, D. McKenna^{5,2}, R. Miteva¹⁵, R. Nag^{1,29}, S. Osłowski³⁷, D. Perrodin¹, A. Parthasarathy^{2,6}, A. Possenti¹, N. K. Porayko^{22,6}, H. Qiu³⁸, A. Ridolfi^{1,6}, K. M. Rajwade², A. Rowlinson^{2,3}, K. Rozko¹⁶, D. J. Schwarz⁷, M. Serylak^{38,39}, G. M. Shaifullah^{22,23,1}, M. Soida⁴⁰, S. C. Susarla²⁶, B. W. Stappers¹³, A. Szary¹⁶, P. Tarafdar⁴¹, G. Theureau^{18,27,16}, S. ter Veen², C. Vocks⁴³, E. van der Wateren^{2,4}, J. Wang⁴⁴, Z. Wu³⁵ and O. Wucknitz⁶